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A Gateway for Access to Solutions for Underwater Radiated Noise

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ABSTRACT

The SATURN (Solutions AT Underwater Radiated Noise) Virtual Research Environment (VRE) is both a gateway and a platform providing deep access technical products generated by the SATURN Horizon Europe project (2021-2025). These outputs are designed to inform understanding of the effects of underwater radiated (URN) noise on aquatic species, and facilitate progress towards implementing the most effective means to reduce harmful biological impacts. The SATURN project generates large amounts of data, software tools, technical outputs, and policy/industrially oriented strategic publications, all of which need to be shared, exploited and preserved. This requires a flexible tool to ensure that information is readily available in line with the requirements expressed by the end-user community. Such a VRE is being developed, deployed and hosted at the PLOCAN facility. Given the scale, and relatively complex set of use-case requirements to be met, it was important to clearly define the scope with clear goals and expectations from the outset. In the present work, we will show a summary of work performed during the course of the SATURN VRE development, which includes: The VRE system requirements and specifications, its main features, and the tools that will be made available to end-users. This work begins with an introduction and the definition of VRE. This is followed by a description of the system specifications with respect to: the VRE within SATURN; the various external target groups; and the VRE tools by use case.

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Finally, we present the conclusions, acknowledgments, and the references. Section 5 (VRE tools by use case) details the different products that will be accessible through the VRE, showing examples of some of the products already available.

1. INTRODUCTION

The SATURN (Solutions AT Underwater Radiated Noise) consortium aims to identify: 1- The sounds that are most detrimental to aquatic species and how they are produced and propagated. 2- The short-term and cumulative long-term negative impacts of noise from shipping and boats on three representative groups of aquatic species in rivers and the sea (invertebrates, fish and marine mammals). 3- The most promising options for measuring and reducing the negative impacts of ship noise that can be applied to current and future vessels. SATURN will also develop and contribute to the establishment of standards for terminology and methodology to be used across all disciplines working on underwater radiated noise [1]. The SATURN project is funded by the H2020-EU program.

The main objective of the SATURN Virtual Research Environment (VRE) is to deliver a resource hub for researchers (bio-acousticians, biologists, marine R&D engineers, etc.) to access SATURN outputs in an interactive way. It will also comprise technical hosting and analytical facilities for processing, analysis and visualization of vessel URN that have been created during the execution of SATURN technical work programmes. More specifically, the VRE enables on-line collaborative experimentation with tools for acoustic signal processing, and acoustic metrics relevant to the impact of underwater shipping noise on aquatic life [2]. Representative samples of recorded acoustic data will be included, which have been selected from available ambient sound-scape recordings and in-situ measurement campaigns. The VRE will also host a novel package of standardized synthetic ship-noise signals [1]. The VRE will also host a selection of datasets and analyses from various controlled sound exposure experiments, which are being conducted to assess the effect of noise on marine animals. These examples highlight the long-term and strategic value of the VRE approach, which is hosted on the PLOCAN server infrastructure, and thereby geared for sustainability beyond the end of the project.

The main purpose of this work is to outline the SATURN VRE tools for noise mitigation: an initial set of utilities defined based on SATURN products that will be made available on-line for research purposes. Familiarity with Jupyter Notebooks and Python programming is recommended to take full advantage of this tool.

2. VRE DEFINITION

Before describing the VRE requirements, specifications and its tools, it is important to define with precision what a VRE system is and learn from the experience in the development of analogous VRE systems [3].

Wikipedia defines a VRE as, "…*an online system helping researchers collaborate. Features usually include collaboration support (Web forums and wikis), document hosting, and some discipline-specific tools, such as data analysis, visualisation, or simulation management. In some instances, publication management, and teaching tools such as presentations and slides may be included* [4]."

The following is the definition provided by the Jisc Virtual research environment program:

"*A VRE helps researchers from all disciplines to work collaboratively by managing the increasingly complex range of tasks involved in carrying out research* [5]." Therefore, a VRE comprises tools, services and technologies that will help researchers do their research, interact with their colleagues and make use of available IT infrastructures.

According to [Candela, et al. 6], VREs are:

- Web-based environments.
- Designed to serve a community of practice.
- Provide tools and services to accomplish the community's goals.
- Open and flexible.
- Promote fine-grained controlled sharing of both intermediate and final research results by guaranteeing ownership, provenance and attribution.

Collaborative online environments for research can be referred to using different terminologies [7]: Collaborative e-Research Communities, Collaborative Virtual Environment, Collaboratory, (Science) Gateway, Virtual Organisation, Virtual Research Community. In this context, the term 'community' refers to the group of persons using the infrastructure, but the VRE is the environment that allows the researchers to interact with each other within a discipline, and across disciplines in the wider scientific and stakeholder community.

3. THE VRE WITHIN SATURN

The role of the VRE in the SATURN project is expressed in the SATURN description of Action in the following terms: “This task will work closely with Task 6.2 and deliver a resource hub for researchers (bio-acousticians, biologists, marine R&D engineers…etc.) to access SATURN results in an interactive way. It will include an advanced housing of technical and analytical tools for processing, analysis and visualization of underwater noise from ships and boats produced by SATURN technical WPs. The environment will allow on-line collaborative experimentation with tools for acoustic signal processing and acoustic metrics relevant to the impact of underwater shipping noise on aquatic life. Data contributors to the VRE will be asked to comply with FAIR principles. From the stakeholder group established in Task 6.2, the task will focus on and engage with researchers interested in underwater noise mitigation and assessment, for requirements and pilot testing. The environment will be deployed and hosted by PLOCAN and connected to the European Research Infrastructure GEANT network to facilitate the sustainability of SATURN results beyond the project lifetime [1].”

4. TARGET GROUPS

Target groups consist of the individuals and organizations towards whom the VRE system is directed to determine the basic requirements of the system. The users’ needs affect the system level complexity, determine the number of necessary features and the way data should be displayed. The VRE under development aims to connect different groups of people from different disciplines. Target groups for the SATURN VRE include [2]:

- Marine acoustic scientific researchers, including academics who conduct research on marine acoustics and its effects on marine life.

- Academic and governmental researchers and agencies, research managers, educators, students, innovators, entrepreneurs and interested citizens who are in charge of making decisions and generating policies.
- Marine industry related companies and businesses, shipowners, shipyards, marine engineering, ship operators, ship builders, product distributors, etc.
- VRE data generator/collector/processors, the partners involved in the SATURN project who provide the data for users, including research institutions and archives, universities, governmental organizations, various researchers and other data publishers.
- Other: At the same time, we envision other potential target groups, such as journalists, educators and students, although these groups are not key to the project.

5. SATURN VRE TOOLS BY USE CASE

A use case is a description of how a person who uses a process or system will accomplish a goal. It is typically associated with software systems but can be used in reference to any process. In our case, SATURN use cases describe through a series of written steps how the users would go about using the VRE to achieve the goals set in the SATURN project description, and the input from the SATURN VRE consultation and stakeholders' meetings. All use cases presented here share the same Jupyter notebook technology [8]. The technology was selected because:

- It is open-source software.
- Widely used.
- Popular within the scientific community.
- Allows users to run, modify and share their code.
- Allows users to read and download data and documents, process, generate and share the results.

5.1. Visualization of Acoustic and Source Level Data Products, Maps and Spectra to Support Reporting and Stakeholders

This use case demonstrates how to visualize acoustic and source level data products, maps and spectra to support reporting and stakeholders' decision making [2]. The following list shows the different sets of data that will be available through the VRE:

- Processed data set of sensors and audio data around each vessel pass (see figure 1 for example power spectra).
- Particle motion and Acoustic Pressure measurements in the larvaebrator [8].
- Table and statistical summary of empirical dose-response relationships.
- Particle motion measurement data from field measurements in the North Sea.
- Particle motion model benchmarks, test cases and modelling results.
- Harmful source level characteristics.
- Particle motion sound maps in different scenarios for Maritime Spatial Planning.
- Underwater Radiated Noise (URN) source level spectra of ship propulsor for propeller and pumpjet for twin-screw vessel.

- URN source level spectra of cavitating ship propulsor with and without bubble injection, and insertion loss due to bubble screen for single-screw vessel.
- URN source level spectra of ship propulsor for trochoidal propeller for twin-screw vessel.
- URN source level spectra of ship propulsor for various propulsor types including waterjet and azimuthal propeller.

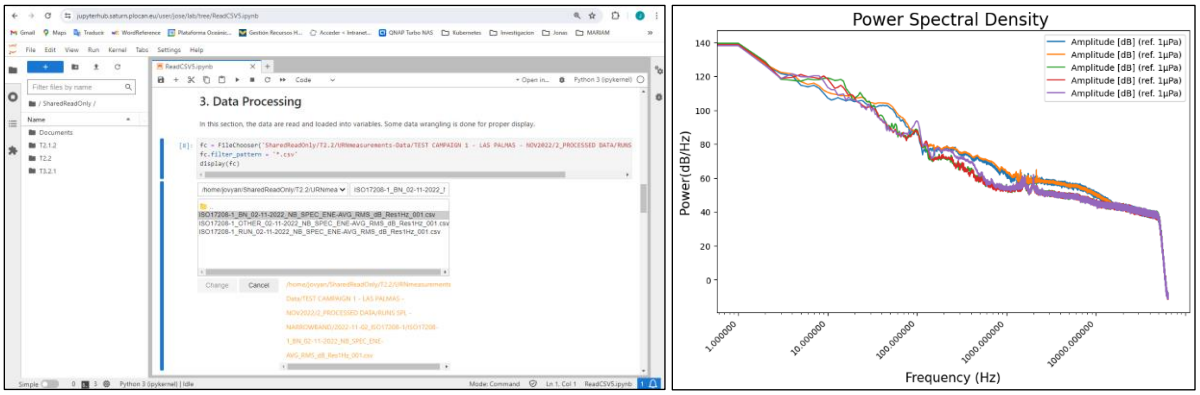


Figure 1: Left: JupyterHub interface showing Notebook for power spectra visualisation. Right: Output spectra from Notebook.

5.2 Processing of Acoustic Data for Standardization, Generating Metrics, and Spatial Planning with Notebooks

This use case demonstrates how to process acoustic data for standardization, generating metrics, and spatial planning with notebooks [2]. These are the software tools that will be available in the VRE:

- Harmonized acoustic metrics, datasets, etc. Integration of "standardization code" within the existing VRE framework (see figure 2).
- Processed dataset and statistical summary and the standardized processing software toolbox.
- Notebook examples of the Maritime Decision Support Tools (DST) workflow.

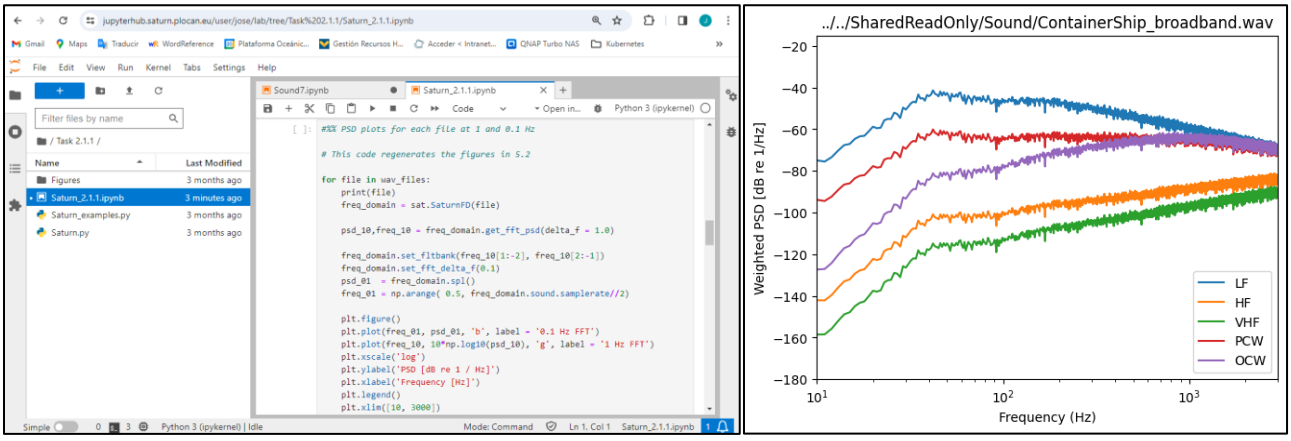


Figure 2: Left: Notebook with “standardisation code.” Right: PSD output of Notebook.

5.3 Inventory of Acoustic Data, Vibration, Environmental Properties and Vessel Operating Conditions

This use case demonstrates how to access and display raw acoustic data, vibration, environmental properties and vessel operating conditions [2]. The following sets of data will be available in the VRE:

- Harmonized ship sound signals. Data files for playback studies. selection of playback signals (see figures 3 and 4).
- Sound library of natural soundscapes in ecologically important parts of fish migratory pathways.
- URN data from measurement campaign. Time domain signals, environmental properties (seabed, water column), vessel operating condition, SL, RNL, PL.
- Onboard vibration measurement. Time domain signals of main machinery and hull plates, operating conditions, decidecade and narrowband spectra.

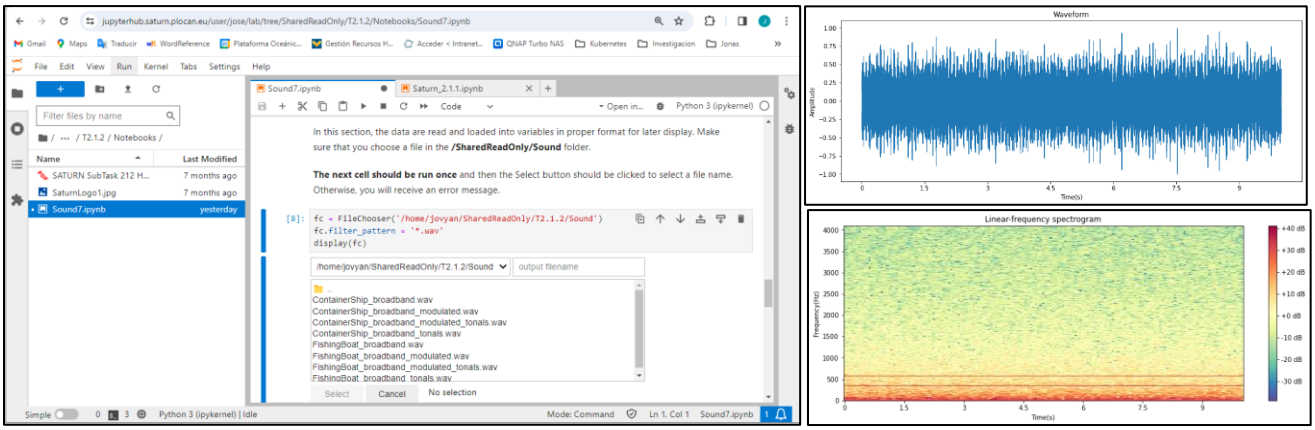


Figure 3: Left: Notebook for sound analysis and playback. Right: Output of Notebook, waveform (top) and power spectrum (bottom).

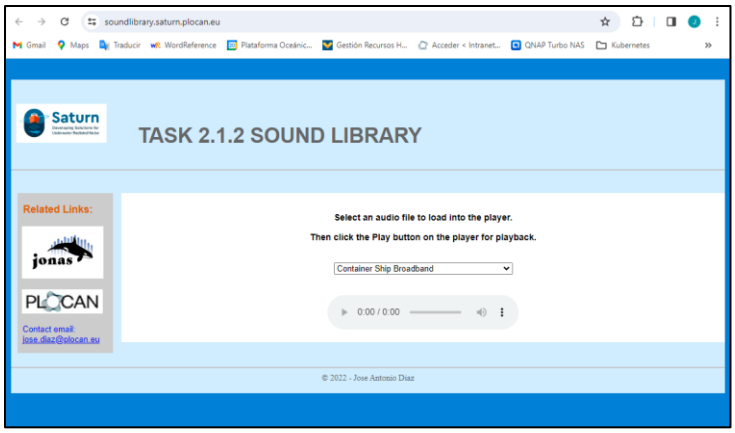


Figure 4: Web page for playback of the ship sound library.

5.4 Access to Reports from Previous Projects and Saturn Research for Teaching and Training Purposes

This use case demonstrates how to access reports from previous projects and SATURN research for teaching and training purposes [2]. The following reports will be accessible through the VRE:

- Lessons from regional projects.
- Population effects of different types of ship noise through the DEPONS model.
- Relationship between health status and animal behavioural changes.
- Ship URN health impact on invertebrates.
- Disturbance impact of vessel noise on migratory fish.

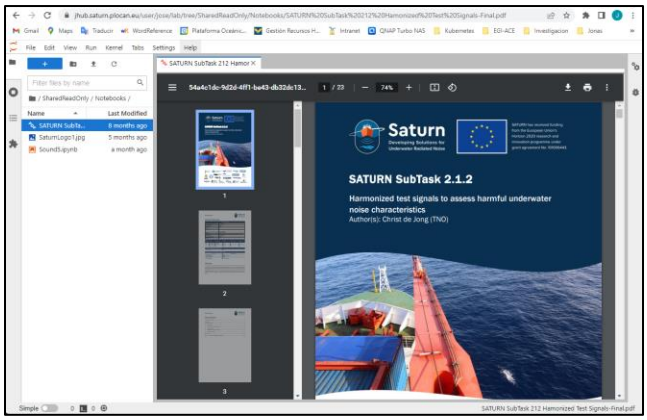


Figure 5: Example report of test signals.

6. ARCHITECTURE

A notebook service is an online command line interpreter to edit and run customized snippets of code and provides a visual interface for accessing data resources and processing software. Jupyter Notebooks deployed from JupyterHub are being used to implement this notebook service.

Docker containers will be provided (including NetCDF for access to noise data files). Docker containers are particularly well suited to bundle applications with all their dependencies and to easily deploy them on different systems.

The Kubernetes container orchestration software is being used to run these docker containers on a cluster.

7. CONCLUSIONS

The development of the SATURN VRE was in large part smoothed by the experience gained in the development of the JONAS VRE [9], and by the lessons obtained from other similar projects. The deployment of the VRE on local in-house servers resulted in a much larger effort than would have the case for an equivalent cloud-based solution, however, the savings in cost and a higher performance outweigh the effort expended. The selection of Kubernetes, JupyterHub and Python also proved to be appropriate, as they are well-suited to fulfill the needs specified in the System Requirements and Architecture document.

The number of inputs to the VRE were relatively large and diverse compared to some other systems (e.g. the JONAS VRE), which necessitated a substantial amount of coordination

and interaction with researchers across other project work packages, and created the need for a high level of attention to integrate the different types of inputs in diverse native formats to ensure high levels of availability to end-users.

In summary, the SATURN VRE is a powerful tool for accessing the products that support solutions to underwater radiated noise provided by the SATURN project, and also allow us to experiment with underwater noise related data, collaborate with colleagues, and share data and results.

ACKNOWLEDGMENTS

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